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ABSTRACT

The 1970 revised science objectives are presented in this booklet along with a summary of the history and goals of the National Assessment of Educational Progress. Procedures used in reviewing and revising the 1965 version are described in detail. The National Assessment Science objectives are divided into three primary statements describing the behaviors expected to be observable in individuals as they move toward the attainment of scientific literacy: (1) Know the fundamental aspects of science; (2) Understand and apply the fundamental aspects of science in a wide range of problem situations; and (3) Appreciate the knowledge and processes of science, the consequences and limitations of science, and the personal and social relevance of science and technology in our society. Each primary objective is divided into subobjectives that deal with the fundamental aspects of science. Each subobjective is further defined with descriptions of related behaviors which are assessed by age levels. Lists of participants in mail reviews and members of panels are appended. (Author/CC)

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SCIENCE OBJECTIVES

For 1972-73 Assessment

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National Assessment of Educational Progress

Science Objectives
for
1972-73 Assessment

National Assessment of Educational Progress
300 Lincoln Tower
1860 Lincoln Street
Denver, Colorado 80203

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PREFACE

The results released to the public by National Assessment in July, 1970, marked the initial reporting based on the first year's assessment of 9-, 13-, and 17-year-olds and young adults between the ages of 26 and 35. National Assessment is now under full-scale operation, and reports will be made continuously as the project collects data describing the knowledge, skills, and attitudes attained by groups of young Americans.

The periodic release of results by National Assessment represents only one aspect of the project. Behind each report lies a complex series of activities that has been completed through the cooperation and participation of thousands of specialists representing a wide variety of disciplines and a number of organizations specifically equipped to handle various operations. From developing educational objectives for a subject area to producing exercises that assess how well those objectives are being met, from constructing a broad and representative sample design to locating individuals in homes and schools throughout the nation for the assessment, from processing the mountains of data collected to finding meaningful ways in which the information can be presented -- countless individuals have completed innumerable tasks before reports are ready for public release.

Nor are the reports that will be released in the next several years -- when assessment in each of the 10 subject areas will be completed -- in themselves the end result of the project. One of National Assessment's main purposes is to compare the educational attainments of groups of young Americans over time. An important use of the first data gathered for each subject area, therefore, is to provide benchmarks against which the results of subsequent reassessments may be compared to determine progress or decline.

The first such reassessment will take place in Science, and the objectives in this booklet are those prepared for the reassessment. These revised educational objectives for the area of Science are presented, along with a summary of the history and goals of National Assessment. The procedures used in developing the revised Science objectives described in the second chapter of this brochure should provide an idea of the time and complexity involved in preparing and revising objectives for each subject area. While the Science objectives are only one part of the overall project, they are a vital and important part. The careful attention given to their development and refinement is typical of efforts made in carrying out other National Assessment activities. The project is an evolving one, and each activity is subject to continuous reexamination and refinement as National Assessment attempts to provide all those interested in what young people are learning with valuable information on the outputs of the American educational system.

Marjorie M. Mastie
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Editors

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Chapter I

INTRODUCTION

The National Assessment is designed to furnish information to all those interested in American education regarding the educational achievements of our children, youth, and young adults, indicating both the progress we are making and the problems we face. This kind of information is necessary if intelligent decisions are to be made regarding the allocation of resources for educational purposes.

In the summer of 1963 the idea of developing an educational census of this sort was proposed in a meeting of laymen and professional educators concerned with the strengthening of American education. The idea was discussed further in two conferences held in the winter of 1963-64, and a rough plan emerged. The Carnegie Corporation of New York, a private foundation, granted the funds to get started and appointed the Exploratory Committee on Assessing the Progress of Education (ECAPE). The Committee's assignment was to confer at greater length with teachers, administrators, school board members, and other laymen deeply interested in education to get advice on ways in which such a project could be designed and conducted to be constructively helpful to the schools and to avoid possible injuries. The Committee was also charged with the responsibility for getting assessment instruments constructed and tried out and for developing a detailed plan for the conduct of the assessment. These tasks required four years to complete. On July 1, 1968, the Exploratory Committee issued its final report and turned over the assessment instruments and the plan that had been developed to the Committee on Assessing the Progress of Education (CAPE), which was responsible for the national assessment that began in February of 1969. In July, 1969, governance of the project was assumed by the Education Commission of the States, a compact of 43 states and territories whose purpose is to discuss and coordinate educational problems and activities.

In the early conferences, teachers, administrators, and laymen all emphasized the need to assess the progress of children and youth in the several fields of instruction, not limiting the appraisal to the 3 Rs alone. Hence, the first assessment includes 10 areas: Reading, Writing (written expression), Science, Mathematics, Social Studies, Citizenship, Career and Occupational Development (originally called Vocational Education), Literature, Art, and Music. Other areas may be added in the future. The funds available were not sufficient to develop assessment instruments in all fields of American education. The 10 chosen for the first round are quite varied and will furnish information about a considerable breadth of educational achievements.

Because the purpose of the assessment is to provide helpful information about the progress of education that can be understood and accepted by

laymen as well as professional educators, some new procedures were followed in constructing the assessment instruments that are not commonly employed in test building.

These procedures are perhaps most evident and important in the formulation of the educational objectives which govern the direction of the assessment in a given subject matter area. Objectives define a set of goals which are agreed upon as desirable directions in the education of children. For National Assessment, goals must be acceptable to three important groups of people. First, they must be considered important by scholars in the discipline of a given subject area. Scientists, for example, should generally agree that the Science objectives are worthwhile. Second, objectives should be acceptable to most educators and be considered desirable teaching goals in most schools. Finally, and perhaps most uniquely, National Assessment objectives must be considered desirable by thoughtful lay citizens. Parents and others interested in education should agree that an objective is important for youth of the country to know and that it is of value in modern life.

This careful attention to the identification of objectives should help to minimize the criticism frequently encountered with current tests in which some item is attacked by the scholar as representing shoddy scholarship, or criticized by school people as something not in the curriculum, or challenged by laymen as being unimportant or technical trivia.

National Assessment objectives must also be a clear guide to the actual development of assessment exercises. Thus, most assessment objectives are stated in such a way that an observable behavior is described. For example, one Citizenship objective for 17-year-olds is that the individual will recognize instances of the proper exercise or denial of constitutional rights and liberties, including the due process of law. Translated into exercise form, this objective could be presented as an account of press censorship or police interference with a peaceful public protest. Ideally, then, the individual completing the exercise would correctly recognize these examples as denials of constitutional rights. It should be noted, however, that exercises are not intended to describe standards which all children are or should be achieving; rather, they are offered simply as a means to estimate what proportion of our population exhibits the generally desirable behaviors implicit in the objectives.

The original objectives in Science were developed in 1965, and were employed in the 1969-70 initial assessment in Science. In preparation for the second cycle of Science assessment, a review and revision of the objectives was initiated in 1969. The procedures employed in the redevelopment of Science objectives, and the revised Science objectives resulting from this process, are described in the following sections.

Chapter II

PROCEDURES FOR DEVELOPING REVISED SCIENCE OBJECTIVES

Burton Voss
Marjorie Barnes

It is generally agreed that the major purpose for teaching science in the schools is to develop scientifically literate citizens. In this regard, a statement made in the early stages of the National Assessment Project is still appropriate:

A comprehensive program in science education must consider two unequal groups of students, those who may eventually pursue scientific careers, and the great majority of those who will not . . . Science education must give a realistic introduction to scientific work for those students capable of it, while at the same time encouraging, developing, and testing their interest and enthusiasm in scientific careers.

Even more attention, however, must be given to the great majority of students who will not eventually pursue scientific careers. In a free society it is the citizens from all walks of life who make the public decisions, and as we proceed in a technological age more of these decisions can be intelligently made only with the knowledge of the scientific considerations which bear upon them.

Also, the success of the general scientific enterprise depends to a great extent on the atmosphere of its surrounding culture. If the general attitude is to be favorable to the scientific enterprise, the public must possess some degree of scientific awareness, at least enough to appreciate the general nature of scientific endeavor, the importance of basic research, and its potential contributions to a better or worse way of life. Thus, for the general student, the schools attempt to produce a scientifically literate citizen favorably disposed toward supporting the work of scientists.¹

¹ Tyler, Ralph and Merwin, Jack. *Working Paper on Objectives*. ECAPE, November 15, 1965, p. 30.

In order to determine whether or not Americans were attaining this general goal of "scientific literacy," National Assessment asked Educational Testing Service of Princeton, New Jersey, to develop a number of more specific sub-goals, or objectives, in 1965. This Educational Testing Service did, following the procedure outlined in the introduction. When the objectives were complete, National Assessment asked exercise writers to use them as the basis for all the Science exercises in the 1969-1970 assessment.

In the summer of 1969, redevelopment efforts aimed at the second cycle for Science commenced. The National Assessment staff chose to handle the redevelopment as an in-house effort, aided by two special science consultants and additional professional assistance when necessary. Accordingly, the review and revision of the 1965 objectives was initiated. This review and revision took place before the results of the initial Science assessment had been tabulated, so a potentially important source of "feedback" was unavailable; nonetheless, the objectives reviewers exploited every other source of constructive reaction to the Science goals to insure the highest degree of clarity, quality, and acceptability.

Review of 1965 Science Objectives

Educational objectives used in the development of exercises for the first cycle of assessment were expected (1) to reflect accurately the contributions of a particular field and (2) to be objectives which the schools are seriously seeking to attain.² Inasmuch as the original set of Science objectives had been prepared in 1965, National Assessment felt that several additional questions should be considered during the development of objectives for the second cycle of assessment in science:

1. Has current thinking by subject matter experts in the field changed as a result of research?
2. Have school practices changed?
3. Have new emphases emerged in the public at large (e.g., ecology)?
4. Have there been significant changes in the art of stating objectives?
5. Has the experience gained through the use of current objectives pointed up problems which need to be remedied?

In order to help determine current validity and relevancy, a mail review of the original Science objectives was conducted early in the summer of 1969. Many of the reviewers had participated in previous reviews for National Assessment. Included were educational researchers, science educators,

²National Assessment of Educational Progress. *Science Objectives*. Ann Arbor, Michigan, p. 2.

members of local and state boards of education, PTA officers, housewives, parents, businessmen, and others involved in education and community service.³

In general, the reviewers approved of the existing objectives, but suggested minor modifications. During the mail review, the staff explored educational journals to locate any relevant information that might have appeared since 1964. Particular attention was devoted to the possible implications of the "newer" science curricula which were likely to have an impact on science teaching.

The information derived from the mail review and the publications research was combined with responses obtained from people who returned a questionnaire (included in the original objectives booklet) which solicited suggestions; then all of this "feedback" was brought to bear on the original Science objectives in making significant revisions. In addition, many objectives and subobjectives were restated in behavioral terms -- that is, in a manner that would permit an observer to judge the attainment of the objectives -- and some statements were rewritten to improve consistency in format.

Review by Subject Matter Specialists

In late July, 1969, a committee of subject matter specialists reviewed the revised version of the Science objectives in Ann Arbor. The group consisted of science educators and teachers, scientists from industry, and representatives of national organizations and curriculum projects. The various science disciplines were represented, as were various geographical regions.⁴ The participants were asked to consider the proposed objectives in light of their own backgrounds and the mood of the times, and to suggest changes, deletions, or additions.

In general, the reviewers accepted individual portions presented in the revised version, with only minor changes. However, after long and thoughtful discussion, they suggested a different structure for the overall organization of the objectives. The proposed structure would reflect the fundamental aspects of the scientific enterprise and would be hierarchical in nature. The fundamental aspects were considered to be: discrete information, laws and principles, conceptual schemes, inquiry skills, and the scientific enterprise. Each of the aspects was to be considered on each of three developmental levels: knowledge, application, and appreciation. The relationship of the aspects and the developmental levels is presented in the matrix or grid shown in Chapter III.

³The participants in the mail review are listed in Appendix A.

⁴The members of the National Assessment Science objectives panel are listed in Appendix B.

Subsequent to the subject matter specialists' review meeting, the Science objectives were reorganized. Many statements in the original objectives were retained nearly intact, and simply "plugged into" the appropriate cells of the grid; some statements were rewritten to provide consistency in format. The set of Science objectives so produced was used at an exercise writers' conference in mid-August.

The purpose of the writers' meeting was to prepare exercises to be used as samples or prototypes for persons who would be developing exercises. During their efforts to write exercises based upon the Science objectives, the prototype writers made several suggestions for changes in the objectives. Such suggestions were considered, along with other suggestions from the subject matter specialists' review panel, and they were added to a later version of the objectives which was prepared for a lay panel review.

Lay Review

The National Assessment Project has always tried to involve thoughtful lay citizens in various aspects of its program. Accordingly, seventeen lay persons were invited to Ann Arbor in mid-September, 1969, to review objectives for Citizenship, Science, and Writing. The panel included a state legislator, lawyers, PTA members, school board members, students, businessmen, and housewives. They were asked to consider certain questions concerning each Science objective:

1. Is it important?
2. Would you want your children to achieve this objective?
3. Is it something being attempted in the schools?
4. Is it consistent with the mood of the times? For example, is it relevant, does it concern social problems, does it distinguish between science and technology?

The members of the panel felt that the proposed objectives were an improvement over the earlier ones. They accepted the Science objectives in general, though they did express some concern that objectives should be relevant to today's problems and that the impact of science on an individual's life should somehow be assessed.⁵

Final Mail Review

Prior to a final mail review early in 1970, further revisions were made in the Science objectives. In the preparation of this version, NAEP considered the modifications suggested in all previous sources — relevant published literature, review panels, questionnaires — as well as the advice of consultants and assessment staff members.

⁵The members of the lay review panel are listed in Appendix C.

Science educators, scientists from industry, lay citizens, and students with differing backgrounds in science -- all from various geographical regions -- consented to take part in a final mail review. Members of the review group were asked to make any appropriate comments or suggestions.⁶ Interestingly, each person seemed to focus on a particular aspect of the objectives such as behavioral terminology, relevancy, age-level delineations, or philosophical factors.

Following the mail review, there still seemed to be inconsistencies which could be classified as philosophical. Accordingly, a science teacher-educator with a special interest in the philosophy of science, and a science objectives specialist were both invited to Ann Arbor for a special conference to consider the objectives from a philosophical point of view. They reorganized and restated some objectives in order to insure a more philosophically consistent set of goals.

A final review of the content and format of the revised Science objectives took place in April, 1971, with three consultants assembling in Ann Arbor.⁷ Following this review, the objectives were prepared in their final form.

The 1970 Science Objectives

The basic individual ideas of the 1965 Science objectives survived an extensive process of review and revision; very few additional objectives were introduced during the preparation of the 1970 revised Science objectives. This attests to the careful work which went into the original document and reaffirms the statement made therein to the effect that the National Assessment Project "had not produced a new set of objectives Rather, these objectives represented a reorganization, a restatement and something of a summarization of objectives which frequently had appeared in print"

Two major changes in the Science objectives occurred during the revision process: (1) the basic structure for presentation was altered to a hierarchical grid, and (2) the objectives were stated behaviorally. These changes bring the Science objectives into better alignment with current thinking about educational objectives and current thinking in science.

⁶Participants in the mail review are listed in Appendix D.

⁷Members of the final objectives review panel are listed in Appendix E.

Chapter III

REVISED SCIENCE OBJECTIVES

The major purpose of science education is to develop scientifically literate individuals. Scientific literacy includes knowledge of the scientific enterprise and of the fundamental aspects of science: discrete information, laws (principles), conceptual schemes, and inquiry skills. Possession of such knowledge is essential to scientific literacy, but in itself is not sufficient; understanding should follow knowledge, and the knowledge should also be applied wherever appropriate. The scientifically literate individual possesses the ability to use the fundamental aspects of science in everyday problem solving and in personal and public decision making. Finally, scientific literacy includes an appreciation of the scientific enterprise and of the various fundamental aspects of science. The essence of science is its usefulness as a powerful tool in the discovery of knowledge by means of observation, experimentation, and problem solving. Learning about the work of scientists or actually engaging in it helps foster an appreciation of science and helps thoughtful individuals acquire favorable attitudes and formulate reasoned value judgments about science.

The National Assessment Science objectives are divided into three primary statements describing the behaviors expected to be observable in individuals as they move toward the attainment of scientific literacy:

- I. Know the fundamental aspects of science.
- II. Understand and apply the fundamental aspects of science in a wide range of problem situations.
- III. Appreciate the knowledge and processes of science, the consequences and limitations of science, and the personal and social relevance of science and technology in our society.

The Science objectives are organized in a manner that shows the relationship between behavioral processes (know, understand and apply, and appreciate) and the fundamental aspects of science. The three primary objectives are actually interdependent, and growth or learning in young people, although it is considered hierarchical to some extent, proceeds concurrently across these three objectives. That is, "knowing" may represent a lower level of interaction with content matter than "applying," and "appreciating," but any one of these processes may in fact precede and give rise to the others. The overall framework for the organization of the Science objectives is shown in the grid following.

*ELEMENTS OF SCIENTIFIC LITERACY:
A TWO-DIMENSIONAL GRID USED IN THE
ORGANIZATION OF THE SCIENCE OBJECTIVES*

Objectives	Fundamental Aspects of Science				The Scientific Enterprise
	Facts and Simple Concepts	Laws (Principles)	Conceptual Schemes	Inquiry Skills	
Know	(I A)	(I B)	(I C)	(I D)	(I E)
Understand and Apply	(II A)	(II B)	(II C)	(II D)	(II E)
Appreciate	(III A)			(III B)	(III C)

The terms appearing in this grid are defined as follows.

Know. To "know" is to recognize or recall phraseology, textual material, or other content. "Knowing" does not include or imply "understanding," "applying," or "appreciating."

Understand and Apply. To "understand" is to be able to explain in one's own words, to recognize when stated in phraseology different from that in the textbook, to interpret, such as in interpreting or drawing inferences from tables or graphs of data. To "apply" is to make actual use of previously acquired knowledge. One must have knowledge and understand that knowledge before it can be applied. For example, one must understand the information on a weather map before he can use it to describe weather conditions in various parts of the country or predict the movement of high and low-pressure areas for several successive days.

Appreciate. To "appreciate" is to value objects, ideas, and processes. Appreciation is expressed behaviorally in willingness to attend, to give up resources for, to take a stand in favor of, etc. One must "know about" in order to appreciate, although he need not necessarily "understand."

Fact. A simple description, definition, or observation that many people can make (for example, "the grass is green"; "the dog has four legs").

Simple Concept. An internalized representation, that is, an individual's generalized idea or mental picture of a property or set of objects, events, or natural phenomena (for example, the idea of "dogginess" as a generalized category that includes specific dogs such as poodles, beagles, and collies). A concept includes at least two facts with an internalized relationship and at least one which is not in agreement.

Law (Principle). A law states a relationship between two or more concepts. (For example, the law "force equals mass times acceleration" tells someone with adequate understanding of "mass" and "acceleration" and knowledge of mathematical symbols how the two terms are related.) Laws are authoritative, can be agreed upon by others, and can be tested. "Law" is presently the preferred term; "principle" is included because it appears in textbooks and reference sources.

Conceptual Scheme. A broad theme of science, a synthesis of a group of interrelated laws (principles). (For example, the theme of complementarity of organism and environment includes relationships between laws of energy resources in the environment, energy pathways, food webs, populations, and communities and ecosystems.)

Inquiry Skills. Those skills needed to engage in the process of science (for example, observation, hypothesis testing, data collection, and ordering of knowledge).

The Scientific Enterprise. The contextual situation in which all science exists; it encompasses everything involved in science: the nature of the scientific method, relationships between science, technology, and society, limitations of science, roles of scientists, and the like.

* * *

Each primary objective is divided into subobjectives that deal with the fundamental aspects of science. Each subobjective is further defined with descriptions of related behaviors which are to be assessed at each age level. The age-level descriptions make the assumption that the objectives are cumulative for 9-, 13-, and 17-year-olds. That is, it is expected that the 17-year-olds know, can do, and appreciate everything that 13- and 9-year-olds know, can do, and appreciate. However, this cumulative effect may not carry over to the adults; they may have forgotten some of the details learned in their formal science instruction. Nonetheless, the adults' understanding and appreciation of science as a process would be developing, especially as science relates to individual and societal problems.

The statement of objectives encompasses the goals of science education for all individuals, both within and outside the schools, and whether science oriented or not. Insofar as is possible, the objectives are translated into behavioral terms, that is, in descriptive statements that permit an observer to judge their attainment. The primary objectives are stated in rather general terms; the subobjectives are more specific; and the age-level descriptions, where provided, indicate the expected behaviors for particular ages. Verb form changes signal this transition from an objective (e.g., "know") to the description of behaviors related to it (e. g., "knows"). More specific descriptions of expected behaviors are reflected in the exercises chosen for assessment: the exercises are selected situations in which attainment of the expected behaviors will be measured.

In general, the age-level descriptions refer to behaviors we expect to be able to observe in individuals at a given age level and may be thought of as a "slice" through the age level, picking up some behaviors shared by the typical subjects, some shared by nearly all, and some by only a few. Where age levels are not mentioned, the assumption is made that individuals at a particular age would give evidence of related behaviors in a manner appropriate to that age.

Section One

OBJECTIVES RELATING TO THE SCIENTIFIC ENTERPRISE

Explanation: The Scientific Enterprise does not fall easily into the grid, or consequently into the organization of these objectives. Larger than the sum of the "Fundamental Aspects of Science," it comprises these plus some overall awareness of the totality, the contextual situation in which all science exists.

Nevertheless, while it may not fall neatly into the present scheme, it represents what may be the most important content of science education and is not to be eliminated for expediency either here or in the classroom.

This statement of objectives begins, therefore, with the three major sub-objectives relating to the Scientific Enterprise:

- I. E: Know the Scientific Enterprise (i.e., have a cognitive grasp of it).
- II. E: Understand and Apply the Scientific Enterprise (i.e., have a valid understanding of it and give evidence of that understanding in one's behavior).
- III. C: Appreciate the Scientific Enterprise (i.e., have one's value system affected by this understanding).

Objectives I A-D, II A-D, and III A and B follow in Section Two, beginning on page 23.

I. KNOW THE FUNDAMENTAL ASPECTS OF SCIENCE

To "know" is to be able to recognize or recall phraseology, textual material, or other content. "Knowing" does not include or imply "understanding," "applying," or "appreciating" the scientific enterprise.

* * *

E. Know the scientific enterprise.

Have a cognitive grasp of the major aspects of the scientific enterprise, including its products, processes, and practitioners, and of the totality of its meaning.

1. Know that laws (principles) of science and technology apply to the solution of problems relating to human welfare. Examples of such problems are conservation of natural resources, environmental pollution, food supply, highway safety, population control, and radiation and fallout.

2. Recognize how scientific knowledge can develop.

For example, recognizes that scientific knowledge can develop both inductively (by observation and experiment and the interpretation of the observations and experimental results) and deductively (by predictions made from existing theories); recognizes that observations and experiments are subject to critical examination, replication, and human error; recognizes that science is both a means and an end.

Age 9 Begins to recognize that science is essentially a search for understanding of the natural world and that it must continually relate itself to observations of that world; recognizes the need for replication in both observations and experiments.

Age 13 Recognizes the need for making relevant, controlled, and accurate observations of natural phenomena under investigation.

Age 17 Recognizes that science observations and experiments must be directed intelligently and proceed within a logical theoretical framework; recognizes that the scientific approach enables one to make sense out of experimental data and to organize it into a comprehensible body of knowledge.

Adult Recognizes that the process of science continually requires a return to the natural phenomenon under investigation for further observations and experiments; recognizes that no natural phenomenon is so completely understood that it is beyond the province of further observation and experimentation.

3. Know that pure science is a search for basic knowledge and that applied science (technology) is a search for uses of knowledge.

Age 9 None.

Age 13 Knows that some research is conducted to develop practical uses for new or old materials; knows that new basic knowledge can come from any research.

Age 17 Identifies scientific projects in current news items as projects in pure science or in applied science.
Adult

4. Know some of the historical aspects of the sciences and technology.
 - a. Identifies important living and nonliving scientists with their contributions.
 - b. Knows that scientific and technological developments depend on the prevailing cultural, economic, social, and political conditions.
 - c. Knows that the events of history have contributed to the scientific enterprise.
 - d. Recognizes the historical sequence of some of the major scientific events; recognizes the cumulative nature of history and of knowledge in science.
5. Recognize that most questions are amenable to inquiry by scientific methods.

Age 9 Recognizes that questions differ in complexity.

Age 13 Recognizes that some questions are much more difficult to investigate than others by scientific methods.

Age 17 Recognizes that some topics for scientific inquiry are more feasible than others and that considerations such as time, urgency, and resources lead to scientific inquiry in some areas but not in others; recognizes that some topics do not qualify as subject matter for science (that is, that for some topics, observations and experiments cannot be made or the results of some observations and experiments are a function of the individual investigator).

Adult Recognizes that religious and social issues are involved in some areas of scientific and technological endeavor; knows that the public interest in, concern about, and moral and material support of scientific inquiry differ greatly depending on the urgency, practicality, and relevance of the inquiry.

6. Recognize that measurement is an important feature of science.

For example, recognizes that the formulation and establishment of laws (principles) are facilitated through the development of quantitative distinctions; recognizes that measurements are approximate by nature and are progressively inclusive and precise.¹

Age 9 Knows that quantitative measurements of natural phenomena can be made.

Age 13 Knows that quantitative measurements provide clearer and more precise representations of natural phenomena than do qualitative descriptions.

Age 17 Knows that quantitative measurements, when feasible, provide the basis for description, hypothesis testing, and prediction; identifies mathematics and statistics as valuable tools for deriving information from quantitative data; knows that all data are not equally precise.

Adult Knows the importance of quantitative measurement in scientific inquiry; recognizes that all measurement is approximate.

7. Recognize that science is not, and probably never will be, a finished enterprise.²

Age 9 Knows that man has always had questions of a scientific nature to explore.

Age 13 Knows that scientific ideas are subject to change and that scientists search continually for the answers to questions.

Age 17 Knows that man continually modifies theories and laws (principles) based on new information, and that scientific theories evolve and are subject to change over a period of time.

¹National Science Teachers Association. *Theory Into Action*. Washington, D. C.: NSTA, 1964.

²National Science Teachers Association, *op. cit.*

Adult Knows that science is always in a state of change and that as new information and technical skills are developed, our present-day scientific knowledge is refined to a greater degree.

8. Have accurate perceptions about scientists as people.

- a. Perceives what scientists are like as people; perceives that their lives and personalities are similar to those of other people and as varied as those of other people.
- b. Perceives the role of scientists as that of uncovering and developing knowledge; knows that there are limitations on what scientists can do; has realistic perceptions of the abilities and power of scientists.
- c. Recognizes the nature of the training and/or experience (sometimes extensive) needed by scientists and technologists.

II. UNDERSTAND AND APPLY THE FUNDAMENTAL ASPECTS OF SCIENCE IN A WIDE RANGE OF PROBLEM SITUATIONS

To "understand" is to be able to explain in one's own words, to recognize when stated in phraseology different from that in the textbook, to interpret (such as in interpreting tables or graphs of data), and to draw inferences from. To "apply" is to make actual use of previously acquired knowledge. One must have knowledge and understand that knowledge before it can be applied.

* * *

E. *Understand and apply the scientific enterprise.*

Have a valid understanding of the scientific enterprise and give evidence of that understanding in one's behavior. Make enlightened use of this understanding of the scientific enterprise.

For example, use this understanding in attempting to interpret everyday occurrences, in guiding daily activity, in personal decision making, and in attacking the problems of society as a whole.

1. Have enlightened understanding of the social and economic consequences of the scientific enterprise.

For example, understands the impact of science and technology on society and the impact of society on science and technology; is aware of the ethics that control the scientist and his work; perceives both the advantages and the dangers of scientific and technological proposals and developments; applies an understanding of the scientific enterprise in evaluating, judging, and working to solve problems relating to human welfare, such as conservation of natural resources, environmental pollution, food supply, highway safety, population control, and radiation and fallout.

2. Make appropriate generalizations about the development of scientific knowledge.

For example, understands that laws (principles) can come about by generalization from observations or by deduction from theories; understands that theories can come about by generalization from laws (principles).

Age 9 Describes the meaning of the definition of science as essentially a search for knowledge; explains the purpose of observations in this search; describes the need for replication in both observations and experiments.

Age 13 Describes the need for relevant, controlled, and accurate observations of natural phenomena under investigation.

Age 17 Understands that science depends on relevant and accurate observations and experiments, and that these observations and experiments must be directed intelligently and proceed within a logical theoretical framework; understands that the scientific approach enables one to make sense out of experimental data and to organize it into a comprehensible body of knowledge; realizes that scientific knowledge is tentative in nature.

Adult Understands that the process of science continually requires a return to the natural phenomenon under investigation for further observations and experiments; comprehends that no natural phenomenon is so completely understood that it is beyond the province of further observation and experimentation.

3. Distinguish between pure science and applied science (technology).

Age 9 None.

Age 13 Begins to distinguish between research for basic knowledge and research for practical uses. For example, given a list of familiar research topics, distinguishes between those which are pure science and those which are technology; realizes that relatively few scientists discover new information but that many technologists develop the consequences of this information.

Age 17 Cites examples of projects which could be considered as pure science and projects which could be considered as technology; describes research mentioned in current news items as basic research or as applied research.

4. Use historical information about the sciences to understand present-day science and technology. An example of such historical perspective is the following: although Newton delineated the scientific principles of putting a satellite into orbit 300 years ago, it has taken much of the time since then to develop the technology to do so.

5. Understand that most questions are amenable to inquiry by scientific methods.

Age 9 Orders questions that differ in complexity.

Age 13 Describes why some questions are much more difficult to investigate than others by scientific methods.

Age 17 Describes why some topics for scientific inquiry are more feasible than others and how considerations such as time, urgency, and resources lead to scientific inquiry in some areas but not in others; explains that some topics do not qualify as subject matter for science; (that is, that for some topics observations and experiments cannot be made or the results of some observations and experiments are a function of the individual investigator).

Adult Describes the religious and social problems involved in some areas of scientific and technological endeavor; understands that the public interest in, concern about, and moral and material support of scientific inquiry differ greatly depending on the urgency, practicality, and relevance of the inquiry.

6. Understand that measurement is an important feature of science.

For example, understands that the formulation and establishment of laws (principles) are facilitated through the development of quantitative distinctions; understands that measurements are approximate by nature and are progressively inclusive and precise.³

Age 9 Understands that quantitative measurements of natural phenomena can be made.

Age 13 Describes how quantitative measurements provide clearer and more precise representations of natural phenomena than do qualitative descriptions.

Age 17 Explains or demonstrates that quantitative measurements, when feasible, provide the basis for description, hypothesis testing, and prediction; explains that mathematics and statistics provide valuable tools for deriving information from quantitative data; explains that all data are not equally precise.

Adult Understands that measurement is important in scientific inquiry and that all measurement is approximate and varies in precision and accuracy.

7. Understand that science is not, and probably never will be, a finished enterprise.⁴

Age 9 Understands that man has always had questions of a scientific nature to explore.

Age 13 Understands that scientific ideas are subject to change and that scientists search continually for the answers to questions.

Age 17 Understands that man continually modifies theories and laws (principles) based on new information, and that scientific theories evolve and are subject to change over a period of time.

³National Science Teachers Association, *op. cit.*

⁴National Science Teachers Association, *op. cit.*

Adult Understands that science is always in a state of change and that as new information and technical skills are developed, our present-day scientific knowledge is refined to a greater degree.

8. Interacts with scientists as with any other people, without the unrealistic expectations, fears, or reverence which would follow from categorization and stereotyping.

III. APPRECIATE THE KNOWLEDGE AND PROCESSES OF SCIENCE, THE CONSEQUENCES AND LIMITATIONS OF SCIENCE, AND THE PERSONAL AND SOCIAL RELEVANCE OF SCIENCE AND TECHNOLOGY IN OUR SOCIETY

To "appreciate" is to value objects, ideas, and processes. Appreciation is expressed behaviorally in willingness to attend, to give up resources for, to take a stand in favor of, etc. One must "know about" in order to appreciate, although he need not necessarily "understand."

* * *

C. *Appreciate the scientific enterprise.*

Have one's value system affected by his understanding of the scientific enterprise. Appreciate the need for, and value, the activities and products of science.

1. Appreciate the nature of the scientific enterprise, especially seeing its emphasis on reason and its opposition to mystical explanation as profoundly shaping the history of western civilization.

For example, appreciates the distinction between science and superstitions or misconceptions and develops reliance on the former; possesses scientific attitudes such as the following (which may be formed relatively early in intellectual development):

- a. skepticism of mystical explanations (for example, horoscopes).
- b. preference for and confidence in scientific explanations.

- c. faith in the possibility of solving problems.
 - d. desire for experimental testing.
 - e. delight in the richer, more exciting view of the world generated by science education.
2. Appreciate the interrelationships within the various branches of science and between science and other disciplines (including the humanities).

For example, perceives mathematics as the language of science. Enjoys the personal discovery of such relationships.

3. Appreciate the interrelationships between pure and applied science.

For example, values both pure and applied science, aware of their different roles.

4. Appreciate scientists; acknowledge the role of scientists in working for solutions to present-day problems; acknowledge the respected place of various scientists esteemed throughout history. Believe scientists are valuable people.

5. Show appreciation of and interest in scientific activities.

For example, engages in science-related leisure-time activities commensurate with own age level, the activities being somewhat independent of school or job requirements (that is, these self-initiated activities may or may not have been stimulated or suppressed by the school or job); remains educable in science.

Age 9 Shows a desire for inquiring about matters such as transportation, construction, techniques of science, astronomy, and industrial processes; begins to show development of interest and curiosity through questions raised about weather, the sky, the earth, living things, machines, transportation, communication, and the natural world; shows interest in science stories, pictures of animals and plants from various regions, conservation, protection of birds and birds' nests, and the making of science collections; begins to develop pride in good workmanship, in

planning work, and in finishing things well, thus becoming critical of own work and making greater effort to improve.⁵

Age 13 Begins to be interested in and inquire about homes, customs, occupations, and products of the different regions of the world; likes to read, hear, or see accounts of man's activities in modifying his environment, in adjusting to it, in inventing ways to use and improve it, and in studying and experimenting to explain it; shows interest in new discoveries and inventions; shows interest in learning the simple scientific principles of sound, light, heat, electricity, and magnetism and exploits these interests outside school as well as in school; derives satisfaction from the use of science books; likes to read about and see various forms of plants and animals; develops science hobbies; begins to develop a respect for good evidence and the nature of proof.⁶

Age 17 Enjoys reading and hearing about science, scientific discoveries, and scientists; develops preferences among the sciences; appreciates the scientific attitude of questioning and suspending judgment; is interested in scientific instruments; recognizes the need for concern about human welfare and about conservation; appreciates the beauty of the orderly, complex, and vast scientific world with its moral and intellectual challenge; and is eager for further knowledge of science.⁷

⁵ Kearney, N. C. *Elementary School Objectives*. New York: Russell Sage Foundation, 1953.

⁶ Kearney, *op. cit.*

⁷ Kearney, *op. cit.*

Section Two

OBJECTIVES RELATING TO THE FUNDAMENTAL ASPECTS OF SCIENCE

Explanation: The remainder of this booklet follows the format established in our grid. That is, each major objective and each subobjective (excluding the last in each case) is taken up in turn.

I. KNOW THE FUNDAMENTAL ASPECTS OF SCIENCE

To "know" is to be able to recognize or recall phraseology, textual material, or other content. "Knowing" does not include or imply "understanding," "applying," or "appreciating" the fundamental aspects of science.

* * *

A. Know facts and simple concepts.

Know factual information and simple concepts representative of various fields of science and technology.

1. Know terminology of science.

For example, is able to define terms, and associate terms with definitions or pictorial representations.

2. Know names and uses of simple equipment used in science work.

For example, is able to associate names and uses with pieces of equipment or their pictorial representations.

3. Know material objects.

For example, is able to associate names with objects or their pictorial representations, state properties, features, structures, etc.

4. Know forms of energy.

For example, is able to associate forms with sources, give characteristics.

5. Know living things.

For example, is able to state names, identify structures, give functions, give characteristics.

6. Know some of the basic concepts of science.

For example, is able to identify types of simple machines, recognize form of atmospheric precipitation, identify classes of common rocks.

7. Know that knowledge can be classified.

For example, is able to recognize simple categories for classifying knowledge.

Age 9 Recognizes that objects can be classified according to common characteristics (for example, that living things can be classified as plants or animals).

Age 13 Recognizes that a particular set of objects may be classified in more than one way.

Age 17 Recognizes commonly used groupings (for example, mammals, birds, and flowering plants; rocks and minerals; Adult metals and nonmetals).

8. Know common mathematical⁸ and scientific symbols.

B. Know laws (principles).

Recognize the relationships involved in laws (principles). Naming the laws (principles) or recognizing the names is not necessary. Representative but not definitive examples include the following:

1. Know Archimedes' Principle, Bernoulli's Principle, or Laws of Motion.

2. Know some principles related to the conceptual scheme of genetic continuity.

⁸Mathematics is fundamental to solving problems in science. Although factual information about mathematics should not be assessed in science, the application of mathematics to science should be stressed.

Age 9 Knows that like begets like.

Age 13 Recognizes that offspring possess characteristics similar to those of the parents.

Age 17 Identifies simple examples of mutation; recognizes some of the natural barriers functioning in the evolutionary process.

Adult Knows that man has been able to manipulate and cause some of the evolutionary changes beneficial to him, especially in agriculture.

3. Know some principles related to the conceptual scheme of conservation of mass-energy.

Age 9 Recognizes the fundamental idea that if a certain quantity exists at a given time, one expects to find it at some later time in the same form or in different forms.

Age 13 Identifies conservation of mass and of energy; recognizes that if a certain quantity exists at a given time, one expects at a later time to identify what may have become of any portion of the original quantity that is missing.

Age 17 Knows that ordinary physical and chemical changes do not alter the mass of matter significantly; knows that the conservation laws must be extended to include both mass and energy if nuclear changes are considered; recognizes conservation laws as they relate to momentum or electrical charge.

Adult Recognizes simple examples of the conservation of mass-energy.

4. Know some principles of classical mechanics.

Age 9 Knows that strong pushes or pulls produce greater changes in motion than weak ones; recognizes the operation of the lever as it relates to simple examples such as teeterboards and scissors; knows that heavier objects require stronger supporting structures than lighter objects; recognizes that some objects can float on water.

Age 13 Recognizes the data needed to determine speeds; knows simple meanings of terms such as gravity, friction, and kinetic energy, although such recognition may be more qualitative than quantitative.

Age 17 Recognizes the distinction between pairs of related ideas such as mass and weight, speed and acceleration, and kinetic energy and potential energy.

Adult Knows about ideas such as gravity, force, velocity, acceleration, weight, equilibrium, inertia, and friction; recognizes that the principles of gravitation, celestial mechanics, and the laws of motion apply, for example, to space flight.

C. *Know conceptual schemes.*

Know some of the fundamental themes that pervade particular fields of science and the broad field of science. Examples of conceptual schemes include those developed for major science curricula (such as the Biological Sciences Curriculum Study or the Earth Science Curriculum Project) or the following seven conceptual schemes of science proposed by the National Science Teachers Association:⁹

1. All matter is composed of units called fundamental particles. Under certain conditions these particles can be transformed into energy and vice versa.
2. Matter exists in the form of units which can be classified into hierarchies of organizational levels.
3. The behavior of matter in the universe can be described on a statistical basis.
4. Units of matter interact. The bases of all ordinary interactions are electromagnetic, gravitational, and nuclear forces.
5. All interacting units of matter tend toward equilibrium states in which the energy content (enthalpy) is a minimum and the energy distribution (entropy) is most random. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.

⁹National Science Teachers Association, *op. cit.*, pp. 22-29, 31.

6. One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid, and gaseous.
7. All matter exists in time and space; and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns.

D. *Know inquiry skills.*

1. Know common approaches to scientific inquiry.

a. Identify common examples of scientific questions.

For example, is able to recognize questions typically associated with a given situation.

Age 9 Recognizes "What?" questions associated with a simple, familiar situation that is commonly taught.

Age 13 Recognizes "How?" questions associated with a simple, familiar situation that is commonly taught.

Age 17 Recognizes "Why?" questions associated with a familiar and situation that is commonly taught.

Adult

b. Recognize statements that qualify as scientific hypotheses.

For example, in familiar problems, is able to recognize when the notion of data is appropriate and is able to state whether or not the possibility of testing a hypothesis exists.

Age 9 Knows that effects occur under reproducible conditions; identifies simple explanations for natural phenomena observed.

Age 13 Knows the nature of a scientific hypothesis; recognizes a simple explanatory hypothesis for a natural phenomenon.

Age 17 States a wide variety of factors that would merit consideration in the formulation of a hypothesis; knows that in the formulation of any given hypothesis some factors are important and others are extraneous.

Adult Recognizes common hypotheses for explaining natural phenomena encountered in daily life.

- c. Recognize important aspects of testing procedures (both logical and empirical) in laboratory investigations which are commonly taught.

For example, in the design of familiar experiments, is able to recognize adequate plans for the collection of data, relevant data, and apparatus setups; is able to identify variables that influence a system, and suitable controls.

- d. Know convention: know ways in which data are expressed, represented, or displayed.

For example, is able to recognize and distinguish among diagrams, graphs, charts, tables, maps, and verbal presentations; knows the quantitative value represented by a numeral.

Age 9 Names the quantitative value represented by a numeral.

Age 13, Recognizes graphs, tables, charts. Distinguishes among Age 17, common forms such as histograms, bar graphs, and line and graphs. Knows commonly taught uses of the various Adult forms.

- 2. Know fundamental techniques associated with inquiry.

Given particular information, distinguish among techniques such as the following which have been used to generate it:

- a. observing.
- b. measuring.
- c. classifying.
- d. communicating.
- e. predicting.
- f. inferring.
- g. knowing appropriate sources of information.

- 3. Know mental elements associated with inquiry.

For example, is able to recognize mental elements in information given.

- a. Identifies familiar instances of fact, law, hypothesis, assumption, and opinion.
- b. Recognizes relevant and irrelevant information in a commonly taught situation.
- c. Recognizes a familiar model and observations the model was invented to describe.
- d. Recognizes observations; recognizes inferences.

For example, given a description of a situation and a set of statements concerning the situation, identifies those statements which are observations.

- e. Recognizes inductive reasoning; recognizes deductive reasoning.

For example, given a set of examples of reasoning, identifies those statements which illustrate reasoning from the general to the specific; identifies this type of reasoning as deductive.

E. *Know the scientific enterprise.* *

See Section One, pages 12-22.

II. *UNDERSTAND AND APPLY THE FUNDAMENTAL ASPECTS OF SCIENCE IN A WIDE RANGE OF PROBLEM SITUATIONS*

To "understand" is to be able to explain in one's own words, to recognize when stated in phraseology different from that in the textbook, to interpret (such as in interpreting tables or graphs of data), and to draw inferences from. To "apply" is to make actual use of previously acquired knowledge. One must have knowledge and understand that knowledge before it can be applied. (For example, one must understand the information on a weather map before he can use it to describe weather conditions in various parts of the country or predict the movement of high and low pressure areas for several successive days.)

* * *

A. *Understand and apply facts and simple concepts.*

Understand and apply factual information and simple concepts representative of all fields of science and technology.

1. Apply terminology of science.

For example, is able to use suitable science terms, when appropriate, in conversations, and to apply correct terminology to observed natural phenomena, including novel situations.

2. Apply knowledge of simple science equipment.

For example, is able to propose uses for simple science equipment, explain the operation of familiar equipment, and designate equipment appropriate for a specified usage in unfamiliar situations.

3. Apply knowledge of properties of material objects.

For example, is able to describe properties, features, and structures of objects and to use this understanding in making decisions, drawing inferences, and predicting outcomes.

4. Apply knowledge of forms of energy.

For example, is able to distinguish between forms of energy, describe sources of energy, and discuss interrelationships of forms of energy.

5. Apply knowledge of living things.

For example, is able to use information about structures, functions, and characteristics of living things in making decisions, drawing inferences, and predicting outcomes; is able to describe and discuss ecological relationships.

6. Use knowledge of basic concepts of science.

For example, is able to explain observations of simple natural phenomena; is able to describe the operation of simple mechanical devices.

7. Use appropriate categories to organize knowledge.

For example, is able to describe categories for grouping objects or living things, describe common characteristics of elements in a group, and classify a group of objects in more than one way; is able to categorize verbal knowledge.

8. Use common mathematical and scientific symbols.

For example, is able to use the symbols to express, record, and interpret scientific data; is able to use the symbols where appropriate in everyday life.

B. *Understand and apply laws (principles).*

Understand laws (principles) of science and apply them in order to solve problems in familiar situations and in situations different from those in which the laws (principles) were learned. Representative but not definitive examples include:

1. Apply Archimedes' Principle, or Bernoulli's Principle, or Laws of Motion.
2. Apply some principles related to the conceptual scheme of genetic continuity.

Age 9 Explains what it means to say that like begets like and uses this understanding to predict and infer unlearned parent/offspring relationships.

Age 13 Understands that offspring are likely to possess characteristics of the parent, and in simplest terms why this is true.

Age 17 Describes simple examples of mutation and the role that natural barriers play in the evolutionary process.

Adult Describes how man has been able to manipulate and cause some of the evolutionary changes that have been beneficial to him, especially in agriculture.

3. Apply some principles related to the conceptual scheme of conservation of mass-energy.

Age 9 Uses the idea that if a certain quantity exists at a given time, one expects to find it at some later time in the same form or in different forms.

Age 13 Applies laws of conservation of mass and of energy to simple examples; (for example, uses the idea that if a certain quantity exists at a given time, one expects at a later time to account for any portion of the original quantity that is missing); uses measurements of quantities to show that the quantities are conserved.

Age 17 Demonstrates or explains that ordinary physical and chemical changes do not alter the mass of matter significantly.

Adult Applies the rule of conservation of mass-energy, especially to everyday problems.

4. Apply some principles of classical mechanics.

Age 9 Understands that strong pushes or pulls produce greater changes in motion than weak ones; understands the operation of the lever as it applies to teeterboards and scissors; demonstrates that heavier objects require stronger supporting structures than lighter objects; applies ideas of floating, for example, to boats.

Age 13 Determines average speeds of objects when given distances and times; selects and/or obtains the data needed to determine speeds; applies ideas such as gravity, friction, and kinetic energy, although understanding of the ideas is probably qualitative rather than quantitative; solves mathematical problems involving these quantities.

Age 17 Distinguishes between pairs of related ideas such as mass and weight, speed and acceleration, and kinetic energy and potential energy; works simple mathematical problems involving force, velocity, acceleration, and energy.

Adult Demonstrates a functional understanding of ideas such as gravity, force, velocity, acceleration, weight, equilibrium, inertia, and friction; may apply enough information about gravitation, celestial mechanics, and the laws of motion to understand, for example, the fundamental mechanical problems of space flight.

C. *Understand and apply conceptual schemes.*

Understand and apply the fundamental themes of particular fields of science and the broad field of science.

For example, apply conceptual schemes to explain, organize, and predict natural phenomena. Representative but not definitive examples include:

1. Use available evidence in interpreting land features.

For example, makes inferences bearing on the age of the earth's crust from evidence seen in sedimentary layers exposed in a road cut.

Age 9 Understands that a particular rock has not always been in its present location and may not always be there; understands that upper layers were formed most recently.

Age 13 Understands that the layers of rock are of varying composition (sandstone, limestone, etc.); explains that the layers were deposited in a succession; explains that the layers may have been formed by different processes.

Age 17 Interprets a sequence of events from the sequence of deposits or other geologic features; speculates about the relative ages of rocks (an intrusion is younger than layers intruded, folding would have occurred later than deposition of the folded layers, etc.).
Adult

2. Use understanding of the fundamental theme of ecology.

Age 9 Understands in simplest terms that some living things are dependent on others.

Age 13 Cites cases where different forms of life live in a single community. Gives simple explanations of how man is upsetting the "balance of nature" in a given community.

Age 17 Explains what man has to do in order to maintain patterns and of interdependence in nature. Uses this understanding in personal decision making.
Adult

D. *Understand and apply inquiry skills.*

1. Apply common approaches to scientific inquiry to answer questions in science and in everyday life.

a. Formulate scientific questions.

For example, is able to formulate a question present in a given situation or suggested by a theory or a prediction, isolate the question from extraneous material, and define the question in specific terms preparatory to devising solutions.

Age 9 Formulates "What?" questions implicit in a simple situation.

Age 13 Formulates "How?" questions implicit in a simple situation; eliminates from consideration the most obvious extraneous conditions.

Age 17 Formulates somewhat complex "Why?" questions implicit in familiar and unfamiliar situations; isolates the questions from extraneous conditions; defines the questions reasonably well in terms appropriate for investigation.

Adult Formulates questions in situations related to real-life experiences rather than in contrived or academic situations.

b. Develop scientific hypotheses.

For example, is able to pose hypotheses that would be most relevant in solving a problem; is able to suggest data that would be pertinent to a problem.

Age 9 Demonstrates that effects occur under reproducible conditions; formulates simple explanations for natural phenomena observed.

Age 13 Understands the nature of a scientific hypothesis; proposes a simple explanatory hypothesis for a natural phenomenon.

Age 17 Considers a wide variety of factors in the formulation of a hypothesis; understands that in the formulation of any given hypothesis some factors are important and others are extraneous; develops a hypothesis with a degree of explicitness and attention to relevant factors that would render the hypothesis useful and testable.

Adult Formulates hypotheses appropriate for explaining or gaining greater understanding of natural phenomena encountered in daily life.

c. Select or propose testing procedures (both logical and empirical).

For example, in designing experiments, is able to propose adequate plans for the collection of data, design apparatus setups, isolate variables that influence a system, and devise suitable controls.

Age 9 Describes what kinds of observations can be made, what experiments can be performed, what data can be gathered, and what procedures can be followed to test a simple explanation for an observation.

Age 13 Plans appropriate observations and/or experiments for testing simple hypotheses, with some attention to relevance, controls, and the degree of precision required.

Age 17 Devises adequate plans for collecting data relevant to testing a variety of hypotheses in familiar and unfamiliar situations.

Adult Proposes suitable plans for the collection of data necessary for testing hypotheses in familiar situations.

d. Obtain pertinent data.

For example, is able to assemble and use laboratory equipment in a logical sequence, select and use appropriate laboratory techniques, make careful observations, and make suitable measurements.

Age 9 Under direction and guidance, collects data based on simple direct observations; collects data in elementary experimental situations.

Age 13 Makes direct observations of natural phenomena as well as measurements of dimensions such as distance, weight, volume, and time; makes these observations or measurements under proper guidance and also independently in familiar areas.

Age 17 Using a self-designed data collection procedure, proceeds independently to make careful observations and/or reasonably precise measurements; has some facility with the use of rulers, balances, and stopwatches and with more specialized apparatus such as microscopes and electric meters.

Adult Makes measurements with simple, commonly available apparatus, the observations and measurements being appropriately relevant and precise.

e. Express data in proper convention and interpret data.

For example, is able to understand the significance of data for hypotheses; uses knowledge of convention to compile and/or interpret data in diagrams, graphs, charts, tables, maps, and verbal presentations; understands the quantitative value represented by a numeral; makes logical predictions from data.

Age 9 Reads numerical values from simple graphs, charts, and tables; reads labels on diagrams; constructs and interprets very simple graphs, charts, and tables; makes simple inferences.

Age 13 Plots data on graphs and arranges data in tables and charts; draws valid conclusions from simple data.

Age 17 Interprets the nature of changes described in diagrammatical, graphical, and verbal data; interrelates different bits of data; judges the relevance and accuracy of statements made on the basis of given data; makes appropriate interpolations and extrapolations.

Adult Interprets cause-and-effect relationships from data; understands that the accuracy of the results of a study depends on the nature of the quantitative data, the size of any samples used, and the adequacy of the study design.

f. Formulate and evaluate conclusions and generalizations appropriate to data or information given or obtained from experiments.

For example, is able to extract from collected data evidence that supports or disproves specific hypotheses.

2. Use fundamental techniques associated with inquiry. Use techniques such as the following in collecting information or in working with information given:

- a. observing.
- b. measuring.
- c. classifying.

- d. communicating.
- e. predicting.
- f. inferring.
- g. consulting appropriate sources of information.

3. Use mental elements associated with inquiry.

For example, is able to use elements in collecting information or in working with information given.

- a. Distinguishes among fact, law, hypothesis, assumption, and opinion, and describes their relationships in inquiry. Generates examples of each.
- b. Distinguishes between relevant and irrelevant information.
- c. Distinguishes between a model and observations the model was invented to describe. Generates examples.
- d. Distinguishes between observations and inferences. Makes observations free of inference.
- e. Distinguishes between inductive and deductive reasoning.

Reasons inductively when appropriate to do so and deductively when appropriate to do so.

4. Attend critically to scientific information presented by the mass media.

For example, is able to evaluate the allegedly scientific or pseudo-scientific; is able to evaluate the adequacy, accuracy, and precision of data; is able to evaluate the use of significant figures, interpolation and extrapolation, statements used out of context, and conclusions drawn from partial data.

Age 9 Begins to restate the obvious important ideas from a written passage or from a media presentation containing scientific information.

Age 13 Extracts the important ideas from reading, listening to, or watching presentations containing scientific information; begins to recognize that the commitment of ideas to media presentation does not establish their truth; determines the gross limitations in the results of an experiment reported in the media.

- Age 17 Evaluates printed materials and media presentations and
 and determines any scientific limitations inherent in them.
 Adult Evaluates conflicting reports and draws tentative conclusions based on analysis of the reports.

E. *Understand and apply the scientific enterprise.*

See Section One, pages 12-22.

III. *APPRECIATE THE KNOWLEDGE AND PROCESSES OF SCIENCE, THE CONSEQUENCES AND LIMITATIONS OF SCIENCE, AND THE PERSONAL AND SOCIAL RELEVANCE OF SCIENCE AND TECHNOLOGY IN OUR SOCIETY*

To "appreciate" is to value objects, ideas, and processes. Appreciation is expressed behaviorally in willingness to attend, to give up resources for, to take a stand in favor of, etc. One must "know about" in order to appreciate, although he need not necessarily "understand."

* * *

A. *Appreciate facts and simple concepts, laws (principles), and conceptual schemes.*

Appreciate science as a dynamic body of knowledge.

1. Be willing or likely to apply basic scientific concepts and laws (Principles), where appropriate, in everyday living.

For example, is willing or likely to apply basic information from own level of sophistication in science to questions involved in personal and public decision making. (The emphasis is on a person's voluntarily applying the scientific information he has, not on how much scientific information he has at his disposal.)

Age 9 At an appropriate level, becomes involved in local campaigns to improve the environment and conserve resources.
 Age 13 sources.

Age 17 Limits use of pesticides, supports legislation for environmental improvements, conserves natural resources.
 Adult

2. Have an interest in current news of a scientific nature.

For example, within own range of understanding of factual content, reads, watches, listens to, and understands current news items on scientifically related topics as they appear in the mass media or occur in conversations; integrates such information into own life.

3. Value the structural framework of science, and the elegance of scientific explanations.

For example, appreciates the interrelatedness of science concepts, and of own volition seeks ways to relate newly acquired information to previous understandings.

B. Appreciate inquiry skills.

Appreciate inquiry skills as fundamental tools for solving problems.

1. Be independently curious about scientific inquiry.

For example, appreciates inquiry skills as techniques which will enable one to discover science knowledge and other knowledge in situations both in and out of school; questions and evaluates inquiry techniques used personally and by others.

2. Participate willingly in scientific inquiry.

For example, is willing and likely to use techniques of scientific inquiry in attempting to answer scientific questions and questions in everyday life.

3. Recognize the importance of having quantifiable data.

For example, in everyday problem situations, prefers obtaining quantifiable data over merely "armchairing" a decision.

C. Appreciate the scientific enterprise.

See Section One, pages 12-22.

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Appendix A

MAIL REVIEW OF REVISED SCIENCE OBJECTIVES

June, 1969*

Educators and Subject Matter Specialists:

Miss Esther Bossung, Elementary School Principal, Louisville Public Schools, Louisville, Kentucky

Dr. Bernardo F. Grossling, U.S. Geologic Survey, U.S. Department of the Interior, Washington, D.C.

Floyd V. Monaghan, Assistant Professor of Physical Science, Michigan State University, East Lansing, Michigan

Dr. Clarence Nelson, Professor, Office of Evaluation Services, Michigan State University, East Lansing, Michigan

Dr. Robert Rainey, Minneapolis Schools, Minneapolis, Minnesota

Dr. H. Craig Sipe, Chairman, Department of Instruction and Professor, Department of Science Education, State University of New York at Albany, Albany, New York

Lay People:

Robert D. Bhaerman, Director of Research, American Federation of Teachers, Washington, D.C.

Edwin D. Bihr, President, Miller Shoe Company, State School Board Association, Columbia, Missouri

Opal Carllson, County Board of Education, Tulsa, Oklahoma

Truman B. Cross, Writer/Consultant, Hubert Humphrey, Washington, D.C.

Mrs. H.K. Cummings, Member, State House of Representatives, Newport, Maine

Clarence J.ENZler, Catholic Education Organization, Bethesda, Maryland

Luther Ford, Board of Education, Minneapolis, Minnesota

Bernice S. Frieder, National Association of State Boards of Education, Denver, Colorado

Marvin Hurley, Chamber of Commerce, Houston, Texas

Hilda L. Jaffe, Board of Education, Verona, New Jersey

Vernard Lundin, President, Minnesota State Board of Education, Mankato, Minnesota

C. Edmund Maag, Delaware PTA, Wilmington, Delaware

Mrs. John Mallory, National Congress of Parents and Teachers, Endicott, New York

Kenneth Meade, Educational Relations, General Motors, Franklin, Michigan

Mrs. John Reid, American Association of University Women, Little Rock, Arkansas

W.L. Robinson, National School Boards Association, College Park, Georgia

Joseph Russell, Attorney, Cape Girardeau, Missouri

Merritt E. Seoville, Board of Education, Glens Falls, New York

Harold V. Smith, National School Board Association, Kearney, Nebraska

Rowan C. Stutz, Utah PTA, Salt Lake City, Utah

Florence S. Young, Shenandoah County School Board, Edinburg, Virginia

Appendix B

SCIENCE OBJECTIVES REVIEW MEETING

July 30 & 31, 1969
Statler-Hilton Inn
Ann Arbor, Michigan

Participants:

- Miss Annie Sue Brown, Science Coordinator, Atlanta Public Schools, Atlanta, Georgia
- Dr. David Butts, Professor of Curriculum and Instruction, Science Education Center, University of Texas, Austin, Texas
- Mr. Robert Carleton, Executive Secretary, National Science Teachers Association, Washington, D.C.
- Mr. Leon Jordan, High School Biology Teacher, Camelback High School, Phoenix, Arizona
- Dr. Laurence Laudan, Chairman, Department of History and Philosophy of Science, University of Pittsburgh, Pittsburgh, Pennsylvania
- Dr. Ralph Lefler, Associate Professor of Physics and Education, Purdue University, Lafayette, Indiana
- Dr. Clarence Nelson, Professor, Office of Evaluation Services, Michigan State University, East Lansing, Michigan
- Dr. Robert Stake, Associate Director, Center for Instructional Research and Curriculum Evaluation, University of Illinois, Urbana, Illinois
- Dr. Joseph Weitz, Director, Earth Sciences Curriculum Project, Boulder, Colorado
- Dr. John K. Wolfe, Manager of University Relations, General Electric Research and Development Center, Schenectady, New York

Consultants:

- Dr. Burton E. Voss, Professor of Science Education, University of Michigan, Ann Arbor, Michigan.
- Dr. Marjorie Barnes, Ann Arbor, Michigan

Staff:

- Dr. Frank B. Womer, Director
- Dr. Irvin J. Lehmann
- Mr. Charles McCormac
- Mrs. Peggy Bagby

Appendix C

LAY REVIEW CONFERENCE, REVISED CITIZENSHIP, SCIENCE AND WRITING OBJECTIVES

September 17-19, 1969
Statler-Hilton Inn
Ann Arbor, Michigan

Participants:

- Mr. Eugene Aleinikoff, Attorney, New York, New York
- Mrs. Ruth Batson, Director, Consultation and Education, Boston University
Community Mental Health, Boston, Massachusetts
- Representative Eugenia S. Chapman, State Legislator, Illinois House of Repre-
sentatives, Arlington Heights, Illinois
- Mr. Willie Davis, Student, Washtenaw Community College, Ann Arbor, Mich-
igan
- Mrs. Jean Dye, Cleveland Heights Board of Education, Cleveland Heights,
Ohio
- Judge Richard C. Eldred, former President, California School Board
Association, Pacific Grove, California
- Mrs. Herbert H. Ferguson, President, Idaho Division of American
Association of University Women, Idaho Falls, Idaho
- Mr. Patrick Finley, Director of Court Services, Wyandotte County Juvenile
Court, Kansas City, Kansas
- Mrs. Carter Goodpasture, National School Board Association, Wichita, Kan-
sas
- Mr. Ed Grafton, Architect, Miami, Florida
- Mrs. Verne Littlefield, past President, Arizona PTA, Phoenix, Arizona
- Reverend Robert C. Loveless, State Board of Education, Honolulu, Hawaii
- Mrs. Suzanne Miller, School Board Member, Whittier, California
- Dr. J.C. Moffitt, Vice-President, Utah PTA, Provo, Utah

Mr. John Noyes, Catholic Education Association, Glen Ridge, New Jersey

Mrs. James Orme, School Board Member, Salt Lake City, Utah

Mr. Paul Parks, Administrator, Model Cities Administration, Boston, Massachusetts

Mrs. Fred Radke, Washington State Board of Education, National School Board Association, Port Angeles, Washington

Miss Pauline Redmond, Student, Detroit, Michigan

Mrs. Olga Riley, Job-Training Programs, U.S. Department of Labor, New York, New York

Mr. Randy Rountree, Student, San Angelo, Texas

Mr. Royal Roussel, Houston Chamber of Commerce, Houston, Texas

Mr. Joseph Russell, Attorney, Cape Girardeau, Missouri

Mr. Robert Lee Scarborough, School Board Member, Eastover, South Carolina

Mr. Jerome Shostak, Education Specialist, Western Electric Fund, New York, New York

Mr. Walter L. Urie, Consulting Engineer, School Board Member, Hardwick, Vermont

Mr. Marvin Wall, Voter Registration Project, Atlanta, Georgia

Miss Terry Wallace, Student, Clovis, New Mexico

Mr. Minoru Yasui, Executive Director, Commission on Community Relations, Denver, Colorado

Mrs. Florence S. Young, Shenandoah County School Board, Edinburg, Virginia

Miss Cynthia Zujkowski, Student, Clarks Summit, Pennsylvania

Contractor Representatives:

Citizenship – Dr. Vincent Campbell, American Institutes for Research

Science — Dr. Burton Voss, University of Michigan
Dr. Marjorie Barnes

Writing — Evans Alloway, Educational Testing Service
Robert Jones, Educational Testing Service

Staff:

Frank B. Womer, Director
Carmen J. Finley, Associate Director
Peggy Bagby
John Bowes
Dale Foreman
Chuck McCormac
Scott Newcomb
Eleanor Norris
Ed Roeber

Appendix D

MAIL REVIEW OF REVISED SCIENCE OBJECTIVES

February, 1970

Subject Matter and Lay Participants:

- Dr. Norman D. Anderson, Professor of Science Education, North Carolina State University, Raleigh, North Carolina
- Dr. Glenn D. Berkheimer, Associate Professor, Science and Mathematics Teaching Center, Michigan State University, East Lansing, Michigan
- Dr. Ernest Burkman, Director, Educational Research Institute, Florida State University, Tallahassee, Florida
- Dr. David P. Butts, Associate Professor of Science Education, University of Texas at Austin, Austin, Texas
- Mrs. June Cofer, Member, Board of Education of the City of Atlanta, Atlanta, Georgia
- Dr. Burton H. Colvin, Head, Mathematics Research Laboratory, Boeing Scientific Research Laboratories, Seattle, Washington
- Dr. George Cossman, Assistant Professor, Science Education Center, University of Iowa, Iowa City, Iowa
- Janna Dreseden, Student, University of Michigan, Ann Arbor, Michigan
- Mr. Leon E. Jordan, Biology Teacher, Camelback High School, Phoenix, Arizona
- Dr. Robert Karplus, Director of Science Curriculum Improvement Study, University of California, Berkeley, California
- Mr. Thomas Lasek, Student, Detroit, Michigan
- Dr. Clarence Nelson, Professor, Office of Evaluation Services, Michigan State University, East Lansing, Michigan
- Mr. Paul Parks, Administrator, Model Cities Administration, Boston, Massachusetts
- Mr. Roger A. VanBever, Supervisor of Elementary Science, Department of Math and Science, Detroit Public Schools, Detroit, Michigan
- Dr. Edward Whiting, The Upjohn Company, Kalamazoo, Michigan
- Dr. John K. Wolfe, Manager of University Relations, General Electric Research and Development Center, Schenectady, New York

Appendix E
SCIENCE OBJECTIVES CONFERENCE

April 29, 1971
NAEP Offices
Ann Arbor, Michigan

Participants:

Dr. Robert C. Craig, Chairman, Department of Educational Psychology, Michigan State University, East Lansing, Michigan

Dr. Paul DeHart Hurd, Professor of Science Education, Stanford University, Stanford, California

Dr. Jack C. Merwin, Dean, College of Education, University of Minnesota, Minneapolis, Minnesota

Staff:

Mrs. Marjorie M. Mastie

Mrs. Lynn Levinson

*Members' affiliations at the time they served on the panel are given.